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16. Abstract

Silicates and chromite in the relatively rare multi-mineral inclusions of the Sikhote-Alin octahedrite are studied. Under X-ray diffraction analysis, separate silicate grains from the three inclusions found were shown to be mostly pyroxene as well as olivine. Tables are included giving X-ray diffraction data (powder patterns) for the silicates and chromite of the inclusions.

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SILICATES AND CHROMITE IN MULTIMINERAL INCLUSIONS OF THE SIKHOTE-ALIN OCTAHEDRITE

by

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Multimineral inclusions containing silicates in the extremely coarse-textured Sikhote-Alin octahedrite are quite uncommon. Three such inclusions in all were encountered in an investigation of numerous samples of this abundant iron rain on their saw-cut planes with a total area of 1 m^2 (Kvasha, 1963). /117*

All three inclusions in the saw-cut planes generally had the form of rounded nodules and had a zonal structure. They were embedded in a mantle made of shreibersite that was interrupted in places and with exterior angular hieroglyphic contours. The components of their minerals were arranged in the following sequence from the periphery to the center: clad schreibersite, troilite, and a core made up of chromite in which portions of silicates are included.

X-ray diffraction investigation of separate grains of silicate from these inclusions showed that they are not only olivine (Kvasha, 1963), but, for the most part, orthopyroxene. We additionally investigated, in this regard, the most preserved multimineral inclusion and the silicates and chromite from other inclusions.

The inclusion from the individual meteorite sample No. 2052 located at a distance of 8—10 cm from the fusion crust was the most complete. It appears in two saw-cut planes of sample

*Numbers in the margin indicate pagination in the foreign text.

No. 2052/23 (photogram 1a, b)*and was discovered to have partially crumbled deeper than these planes, which allowed it to be observed at different levels. The dimensions of the inclusion at the larger saw-cut plane was approximately 18 X 15 mm together with its veiled schreibersite. The troilite immediately after the schreibersite forms a mantle; its outer boundary with the schreibersite has a regular oval form, while the inner boundary with the chromite is irregular. Troilite in the form of rounded contour projections, so-called 'inflows,' penetrates the chromite. Troilite evidently composes an ellipsoidal mantle. It is necessary to note a perfect cleavage in it whose plane is perpendicular to the surface of the mantle. The 'core' of the inclusion is composed of chromite which in turn includes an individual section of silicates with dimensions of about 6 X 3 X 2 mm with tail projections with irregularly shaped inflows. The boundaries of the inflows with the chromite have rounded countours that are the same as the inflows of troilite in chromite.

The principal mass of the silicate was a light-emerald greenish and transparent mineral with a perfect cleavage along which it was easily broken when squeezing the indenter into fine fragments that turned the sites into a white powder. The silicate along the boundary with the chromite is in places fine grained and takes on a brownish tint.

The silicate is colorless or has a slightly greenish tint /118
under a microscope in submerged slides in thin fragments, and reveals a perfect cleavage relative to which it extinguishes in parallel It sometimes contains microscopic inclusions of nontransparent minerals and air holes.

Its refractive index measured in submerged liquids are: $N_g = 1.688 \pm 0.002$; $N_p = 1.674 \pm 0.002$. The angle of the optical

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*Translator's Note: photos are not reproduced in this translation.

axes was about 70°, and was positive (determined by the interference figure). Elongation was positive. According to these data it corresponds to orthopyroxene-bronzite, containing about 18 mol.-% Fs (Dir et al., 1965, Vol. 2). The X-ray diffraction data are presented in Table 1.

TABLE 1 - INTERPRETATION OF THE POWDER PATTERNS OF SILICATE MINERALS

Sample No. 2052/23		Bronzite (Kovalev et al., 1959)			Sample No. 170-p		Olivine (Yelliseyev, 1957)		
I	d/n α Å	I	d/n α kX	hkl	I	d/n α Å	I	d/n α kX	hkl
1	4,00	2	4,02	211	3	5,01	6	5,13	020
2	3,31	2	3,31	121	2	4,66			
10	3,16	10	3,17	420; 221	2	4,22			110
3	2,94	4	2,95	321	5	3,90	9	3,893	021
5	2,88	8	2,88	610	2	3,74	4	3,724	101
1	2,84	2	2,83	511	3	3,48	6	3,494	111; 120
3	2,71	4	2,71	421	—	—	4	3,333	030
4	2,54	6	2,54	131	3	3,02	3	2,985	002; 121
8	2,50	6*	2,48	231; 521; 202	8	2,78	10	2,772	130
1	2,37	2	2,38	302	8	2,52	10	2,508	131
1	2,26	3	2,25	711	9	2,46	10	2,455	112
7*	2,11	7*	2,10	502	1	2,34	2	2,326	041
2	2,05	3	2,06	512	9	2,27	8	2,263	140
2	2,03	4	2,03	811; 141	3	2,17	4	2,158	211; 220
2	1,987	5	1,989	440	—	—	2	1,880	150; 202
4	1,954	6	1,958	631	—	—	2	1,787	151
—	—	1	1,887	821	10	1,753	10	1,747	222; 240
1	1,829	1	1,837	702	1	1,676	3	1,670	241
1p	1,794				2	1,639	3	1,640	061; 232
2*	1,774	4	1,781	541	2	1,622	3	1,617	133
1	1,734	4	1,736	[illegible]	2	1,572	2	1,568	043; 310
[illegible]	1,698	2	1,702	10.11	3	1,501	6	1,496	004
1	[illegible],681	2	1,680	812; 142	4	1,484	6	1,479	062
3	1,607	4*	1,609	023; 902	4	1,392	5	1,394	233; 312
1	1,586	4	1,592	931	5	1,352	6	1,349	322; 340
1	1,527	3	1,533	650	4	1,318	4	1,314	134; 341
1	1,516	4	1,522	12.00	—	—	1*	1,295	044
8	1,486	9	1,489	10.31	1	1,189	3	1,188	400
4	1,473	7	1,477	600	1	1,169	2	1,179	333; 025
1	1,417	7	1,423	352					
5	1,393	8	1,396	11.31					

Note: p-- diffuse lines

* - wide lines

[Translator's Note: commas represent decimals]

Two other inclusions encountered in a fragmented specimen (Sample No. 170-p) are located a small distance from each other (photogram 1c). They are not cut by the saw-cut planes very deeply, as is particularly evident by the shallow chromite zone through which the schreibersite or nickel iron shows. Two parts of a phacoidal form with rounded contours, composed of colorless transparent sili- /119 cate grains, brownish in places, are found in the smaller formation in the middle of the sparkling chromite.

We were able to measure only the average index of refraction Nm = 1.686 $\pm$ 0.004 and to obtain a mineral in the interference figure (straight beam) with angle of the optical axes 2V of about $\pm$ 90° in separate granules of the mineral extracted from the smaller inclusion. According to these data it may belong to olivine with a content of about 19 mol.-% Fa (Dir et al., 1965, Vol. 1). The reason for the deviation from earlier data (Kvasha, 1963) can be either the previously understated estimate of the refractive indices or variations in the olivine composition.

Fine fragments of silicates from the multimineral inclusions of samples No. 2052/23 and 170-p were chosen for X-ray diffraction analysis.

Powder patterns were obtained from unfiltered iron radiation (35 kV, 14 mA) in the RKD-57.3 camera. The distance between the middle lines on the powder patterns was measured on the IZA-2 comparison meter and the intensity (I) was estimated visually on a ten-point scale. The Hiemstra technique (Hiemstra, 1956) was used on account of the small quantity of material for photographing.

Some difference in the intensities of the lines and in the size of the interplane distances of the standard X-ray diffraction patterns of orthopyroxene and olivine and the X-ray diffraction patterns of the samples investigated can be explained by differences in their compositions (see Table 1).

The lattice parameters were not calculated since the photograph and computation of the X-ray diffraction patterns was performed without allowance for error. The Fs content in orthopyroxene was determined according to the pattern of the dependence of the difference in the value d for reflections (0.6.0) and (10.3.1) (Zwaan, 1954) and amounted to about 17-18 mol.-% Fs, which defines orthopyroxene as a bronzite. The amount of Fs in olivine was estimated according to the pattern of the dependence of d_{130} on composition (Yoder, Sahama, 1957) and amounted to about 19-20 mol.-%.

In addition to X-ray diffraction patterns of the silicates, an X-ray diffraction pattern was obtained for chromite from inclusion No. 2052/23 and for chromite from a chromitic nodule of the largest individual specimen of the Sikhote-Alin meteorite No. 1821 (Table 2).

TABLE 2 - INTERPRETATION OF CHROMITE POWDER PATTERNS

Sample 2052/23		Sample 1821		Chromite (Stulov, 1960), Sample 9		
I	$\frac{d}{n}$ α Å	I	$\frac{d}{n}$ α Å	I	$\frac{d}{n}$ α kX	hkl
2	2,932	1	2,940	2	2,943	2 2 0
10	2,520	10 ш.	2,509	10	2,513	3 1 1
		—		1	2,404	2 2 2
3	2,091	7 ш.	2,084	7	2,081	4 0 0
		1	1,696	1	1,701	4 2 2
5	1,608	8	1,607	7	1,604	3 3 3
7	1,478	9	1,476	9	1,473	4 4 0
2	1,277	[illegible]	1,276	1	1,270	5 3 3
		2	1,257	1	1,255	6 2 2
1	1,205	2	1,205	1	1,201	4 4 4
				1	1,111	6 4 2
6	[illegible]	5	1,087	4	1,084	5 5 3
5	[illegible]	2	1,045	2	1,041	8 0 0
a	8,36		8,35		8,346 ± [illegible]	

The lattice parameter of the chromite was determined as the arithmetic mean, calculated according to the lines with intensity (I) above 3. /120

The contents of the series of chemical elements were determined for these same chromites by G. M. Kolesov and A. P. Shpanov by the method of instrument neutron-activation analysis (Table 3).*

TABLE 3 - RESULTS OF A NEUTRON-ACTIVATION ANALYSIS OF CHROMITE

Element	Isotopes and gamma radiation energy, keV	Exposure time of sample, days	Content, wt.-%	
			Sample No. 1821, weight 1.15 mg	Sample No. 2052/23.2, weight 1.19 mg
Cr	51 Cr; 320,0	14	43,1	47,4
Fe	56 Fe; 1291,5	14	10,7	14,7
Mn	56 Mn; 846,9	1	$3,7\cdot10^{-1}$	$6,2\cdot10^{-1}$
Ni	65 Ni; 1481,7	0,3	$<6\cdot10^{-2}$	$<6\cdot10^{-2}$
Co	60 Co; 1332,4	14	$1,2\cdot10^{-3}$	$1,6\cdot10^{-3}$
Na	24 Na; 1368,4	1,3	$8,9\cdot10^{-3}$	$4,3\cdot10^{-2}$
K	42 K; 1524,7	0,5	$6,9\cdot10^{-3}$	$3,7\cdot10^{-2}$
Ga	72 Ga; 630,1	1,3	$2,5\cdot10^{-3}$	$1,6\cdot10^{-3}$
Sc	46 Sc; 1120,3	14	$<4,6\cdot10^{-4}$	$<5,7\cdot10^{-4}$

The samples of chromite and the standards of the elements determined were placed in quartz ampoules, wrapped in aluminum foil, and irradiated in an atomic reactor with a neutron flux of $1.2\cdot10^{13}$ neutrons/cm^2·sec for 20 hrs. Following irradiation the samples and the standards were transported to glass test tubes to eliminate background activity of the ampoules and foil and were measured on a high-resolution gamma spectrometer with Ge(Li)-analyzer and a 4096-channel pulse analyzer, equipped with an elecronic computer. We measured several times the time interval that was optimal for each isotope for more reliable determinations of the elements (see Table 3). The contents of the elements were

* I wish to express my appreciation to G. M. Kolesov and A. P. Shapnov (Vernadskiy Institute of Geochemistry and Analytical Chemistry of the U.S.S.R. Academy of Sciences) for conducting the analysis.

calculated by the percentage method for areas of the most intensive photopeaks of the radioisotopes in the spectrum of the sample and and standard. The error in the analysis did not exceed $\pm$ 15%.

A comparison of the X-ray diffraction and chemical (D'yakonova, 1963) data indicates that chromite from the silicate inclusion investigated is more ferrous than chromite from the nodule of sample No. 1821 (see Tables 2 and 3). Only divalent iron is part of the chromite from sample No. 1821 according to the data of the Mossbauer spectrum (partial report of T. V. Malyshevaya).

According to the data obtained, mineral association of inclusions in the Sikhote-Alin meteorite are simpler associations of multi-mineral inclusions from other iron meteorites (Brünch et al., 1970). However, our investigations were limited to mineral grains chosen from separate parts of the inclusions (without investigating microsections), which does not exclude the presence of other minerals in them.

The Mg/Fe ratio in orthopyroxene and olivine corresponds to the equilibration ratio of these minerals. The discovery of these two minerals in different inclusions and the form and structure of these inclusions themselves do not contradict their syngenesis in the meteorite.

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